Material solutions to mitigate fire, smoke and fumes in the cabin environment

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Aim of WP7.2

Background

- 50% of fatalities are linked to situations where fire is involved
- Inflight or post-crash scenario
- Increase of commercial aircraft traffic and use of composite materials: Contribution to safety with respect to fire related issues needed

Objectives

- Develop and utilize novel and innovative <u>material solutions</u> with high potential <u>for mitigating risks of fire, smoke and fumes</u> in the cabin environment.
- The scope and magnitude of proposed <u>test plan respect industrial safety requirements</u> and usage of state-of-the art simulation tools
- <u>Improve</u> state-of-the art <u>simulation</u> <u>tools</u> to decrease experimental effort and to increase understanding

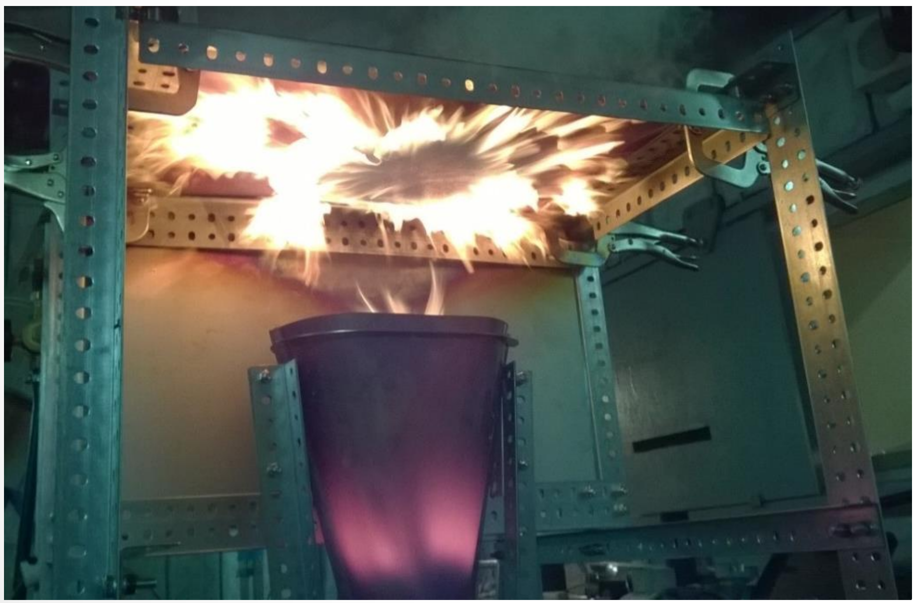
Outline

- Simulation of fire testing
- Overview to Material solutions with promising FST behavior
  - Geopolymers
  - Fibre metal laminates
- CuFEx facility
- Test results
- Demonstrator
- Outlook

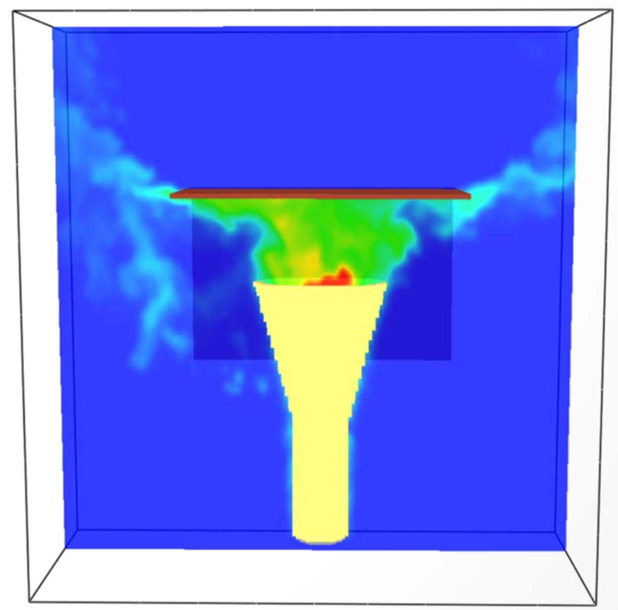
Simulation of fire testing

Numerical simulation to reduce experimental effort

- Simulation of flame penetration tests by coupling of CFD and CSM analyses
- Modelling of pyrolysis to capture the reactions of produced gas



Flame penetration test

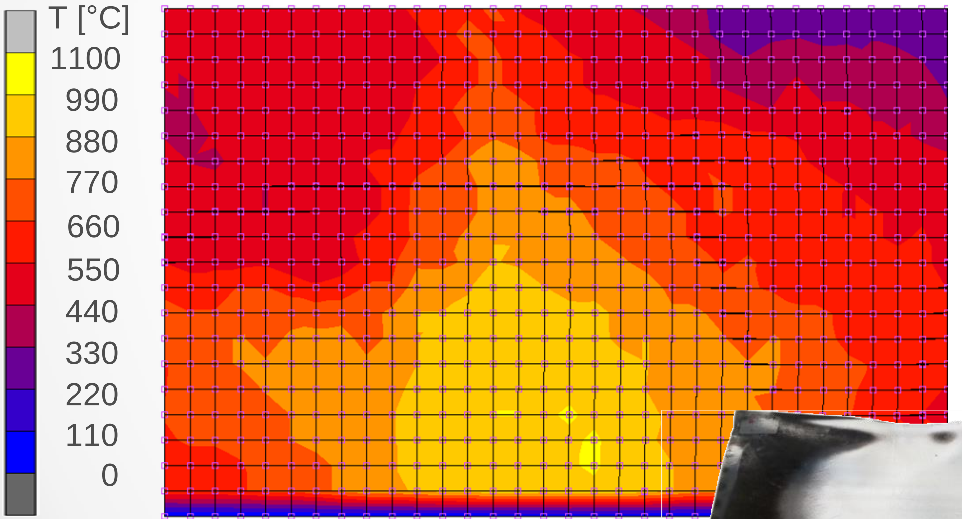


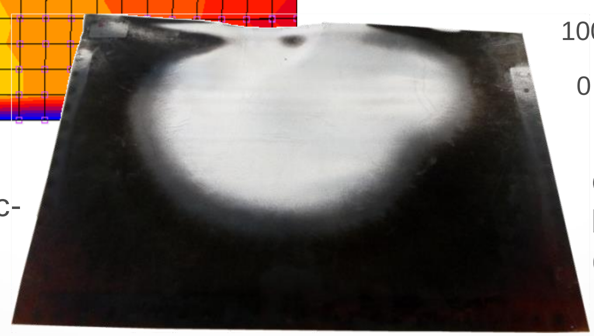
CFD model (FlamePTM)

Simulation of fire testing

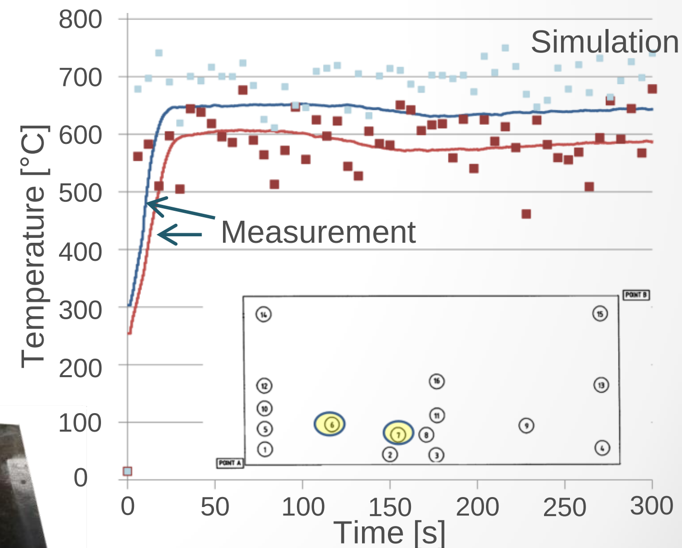
Numerical simulation to reduce experimental effort

- Simulation of flame penetration tests by coupling of CFD and CSM analyses
- Modelling of pyrolysis to capture the reactions of produced gas
- Validation of the thermo-structural behavior shows good agreement





Comparison of temperature distribution of simulation to burnt area of a common phenolic-glas specimen after flame penetration test

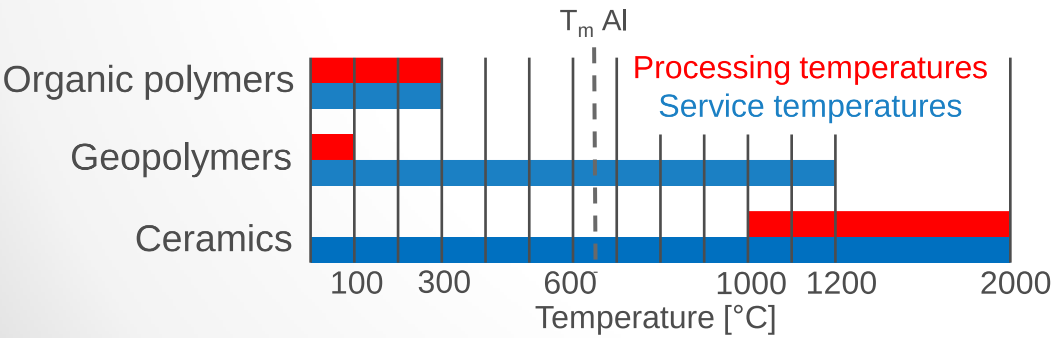


Comparison of temperature history between experiment (lines) and simulation (points) at 2 positions

Geopolymers

Low temperature processing

- Ingredients: Metakaolin, silica (SiO_2), water and „water glass“ as activator
- Manufacturing:
  - High speed mixing of ingredients at room temperature
  - Wet laminating, Prepreg
- Can be worked up like common resins at low process temperatures



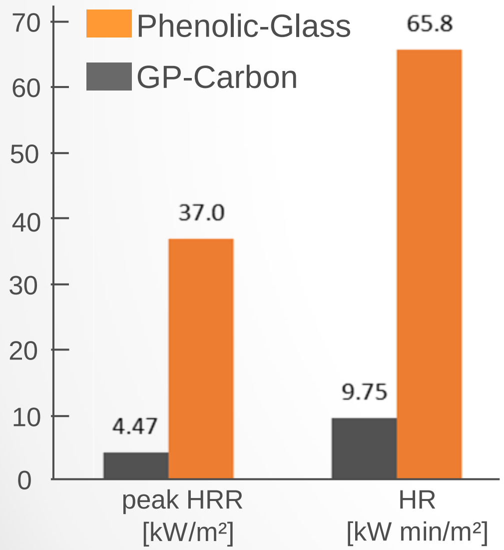
Wetpreg preparation machine

Wetpreg prepared for laminate layup

Geopolymers: Test results

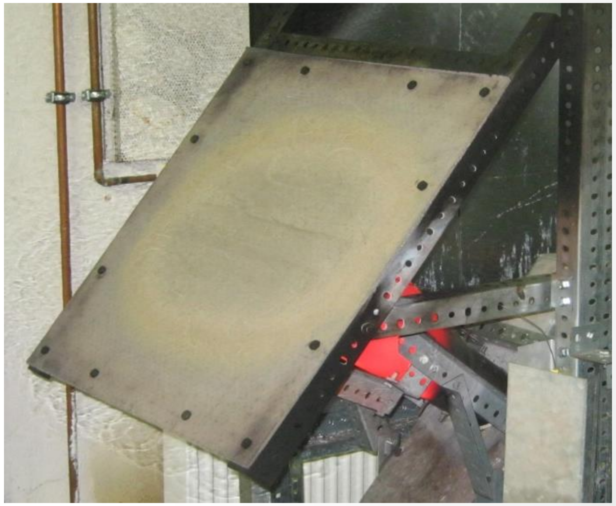
Promising FST behavior of GP

- Anorganic polysialate matrix withstands temperatures above 1000°C
- Burn through results: No fire penetration was registered at any of test



Heat release rate

Phenolic-Glass

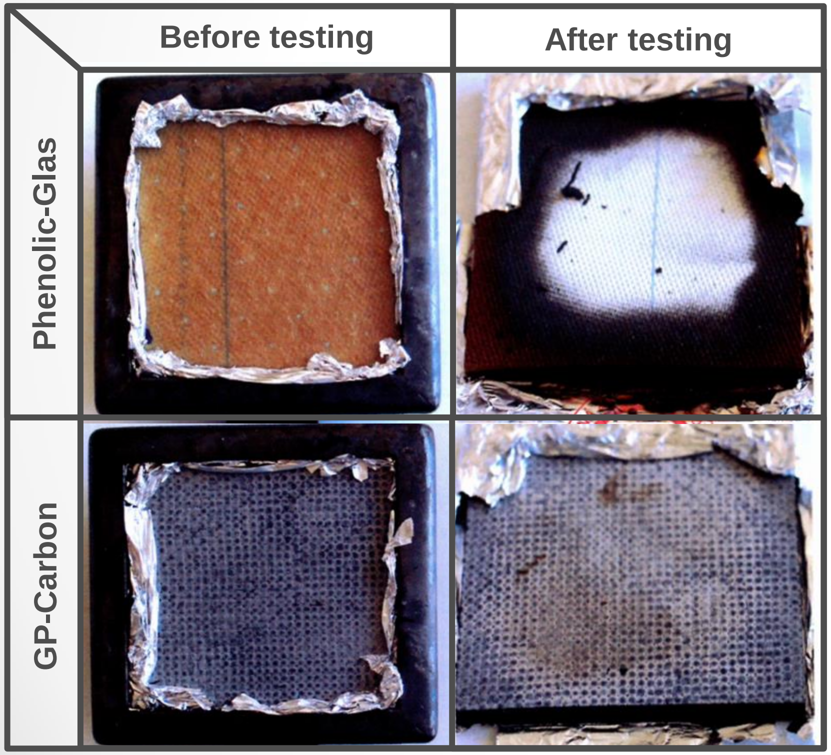


GP-Carbon

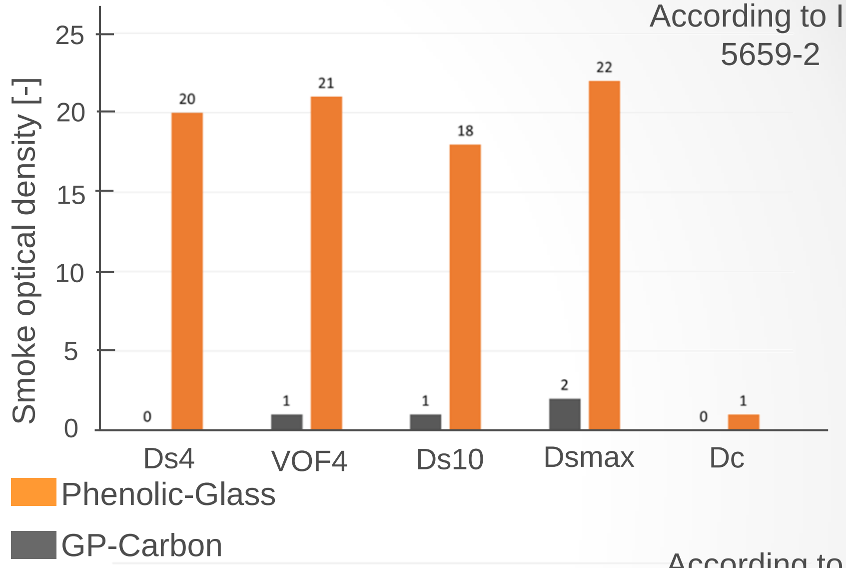
Test of resistance to fire in designated fire zones per ISO 2685

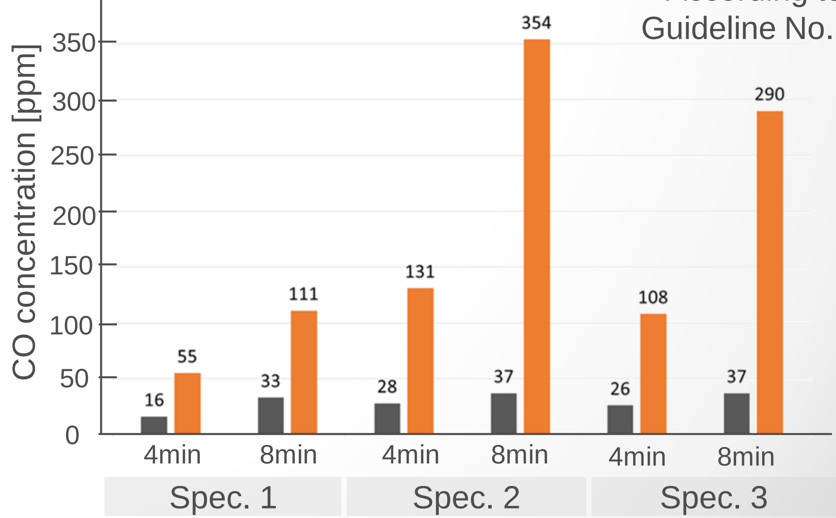
Geopolymers: Test results

Almost zero generation of toxic products or smoke wrt fire exposure



Specimens before and after test: GP shows almost no influence whereas phenolic resin is completely burnt off

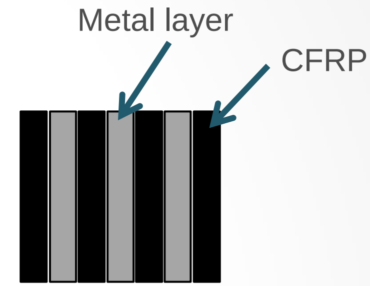




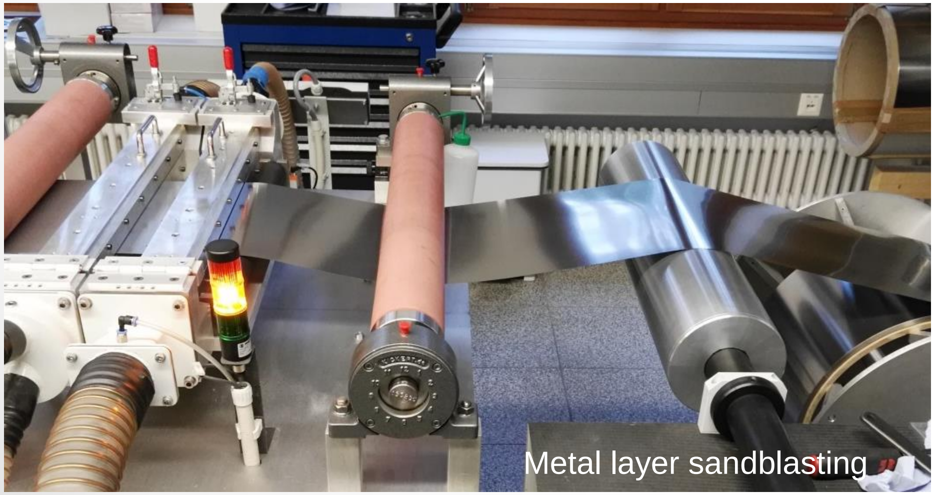
Fibre metal laminates

Manufacturing close to standard processes

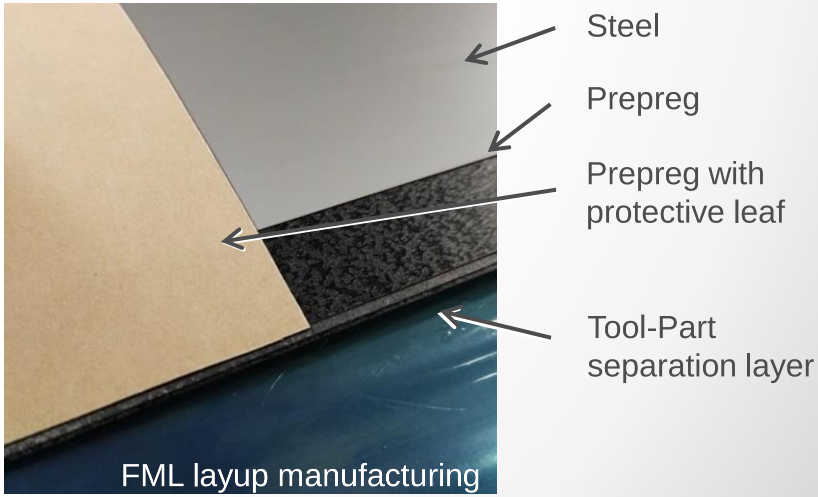
- Utilization of common prepreg autoclave curing processes
- Additional preparation of metal sheets
  - Sandblasting
  - Bonding agent
- Variation of metal layer thickness and metal layer positions investigated



Manufactured FML cross section



Metal layer sandblasting

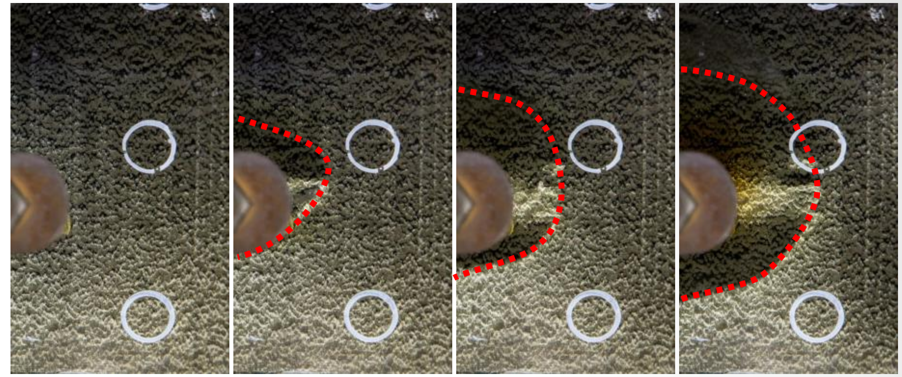


FML layup manufacturing

Fibre metal laminates

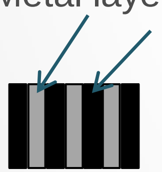
Developping heat barrier

- Melting temperature of steel > 1200°C
- Decomposition of matrix creates gases
- Metal layers act as gas barrier
- Decomposition gasses are trapped (Pillow effect) and act as insulation
- Rear layers survive within a fire scenario (no decomposition)



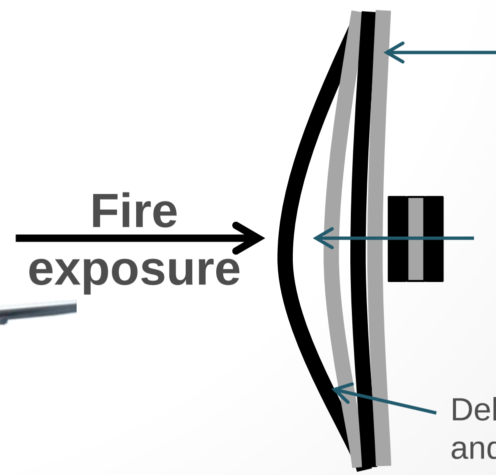
Pillow effect & its growth progression wrt fire exposure time

Undamaged FML



Possible fire scenario

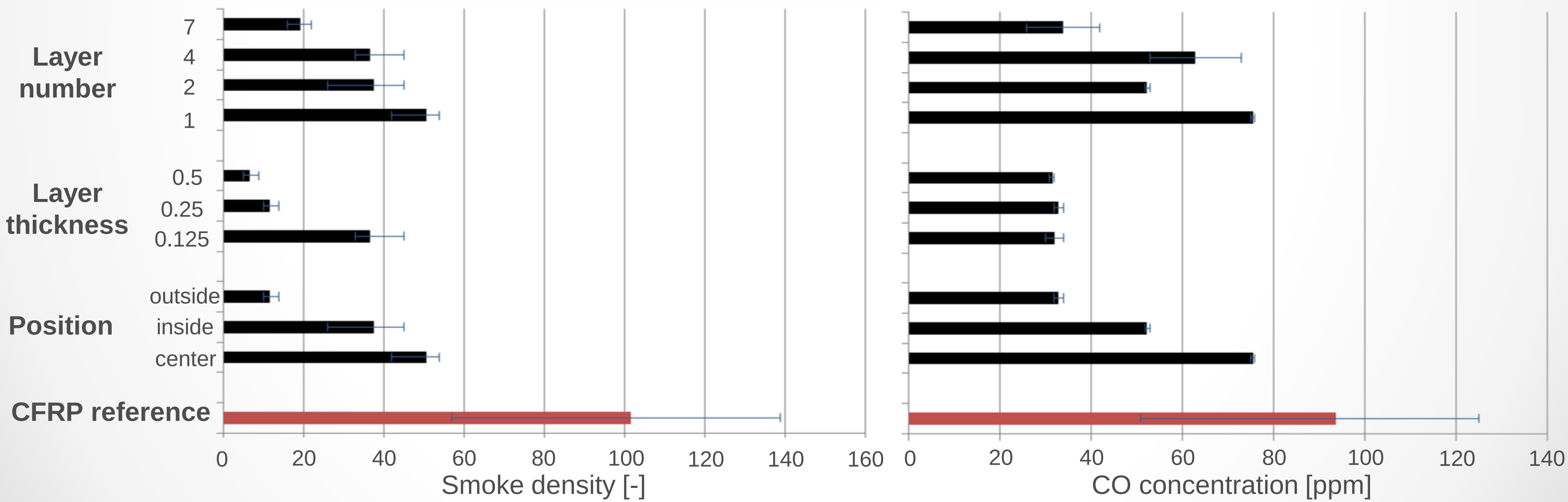
Damaged FML



Fibre metal laminates

Promising FST behavior

- Variation of metal layer numbers (wrt equal metal content)
- Variation of metal layer thickness (wrt to equal number and position)
- Variation of metal layer position (wrt equal metal content and layer number)



Summary to investigated material solutions

Both, Geopolymers and Fibre Metal Laminates show significant improvement of FST behavior (Smoke density and Smoke Toxicity)

- Geopolymers withstands the high temperatures
- FML create gasses that are trapped between the metal layers. The resulting insulation effect prolongates rear layer life

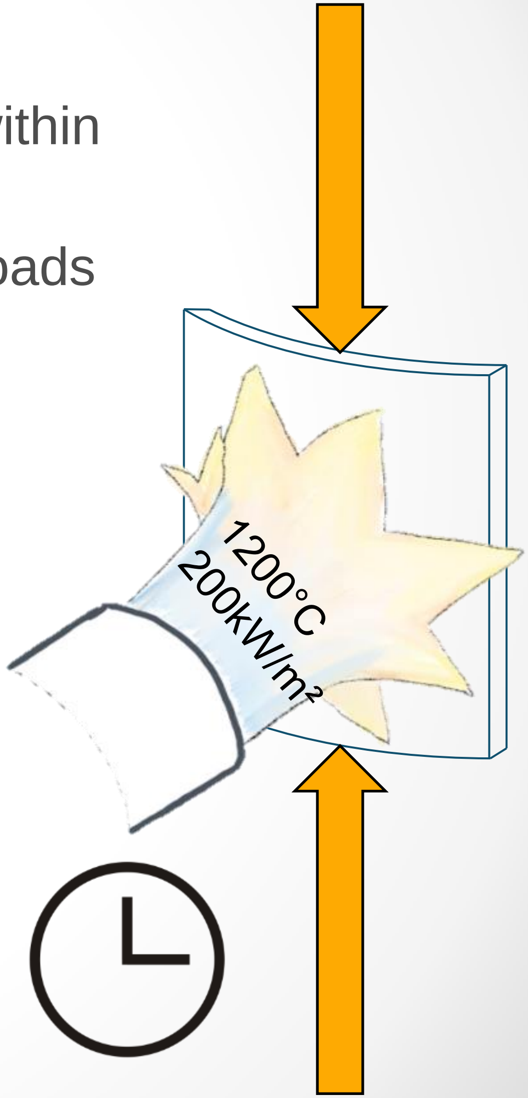
CuFEx facility

Compression under Fire Exposure (CuFEx)

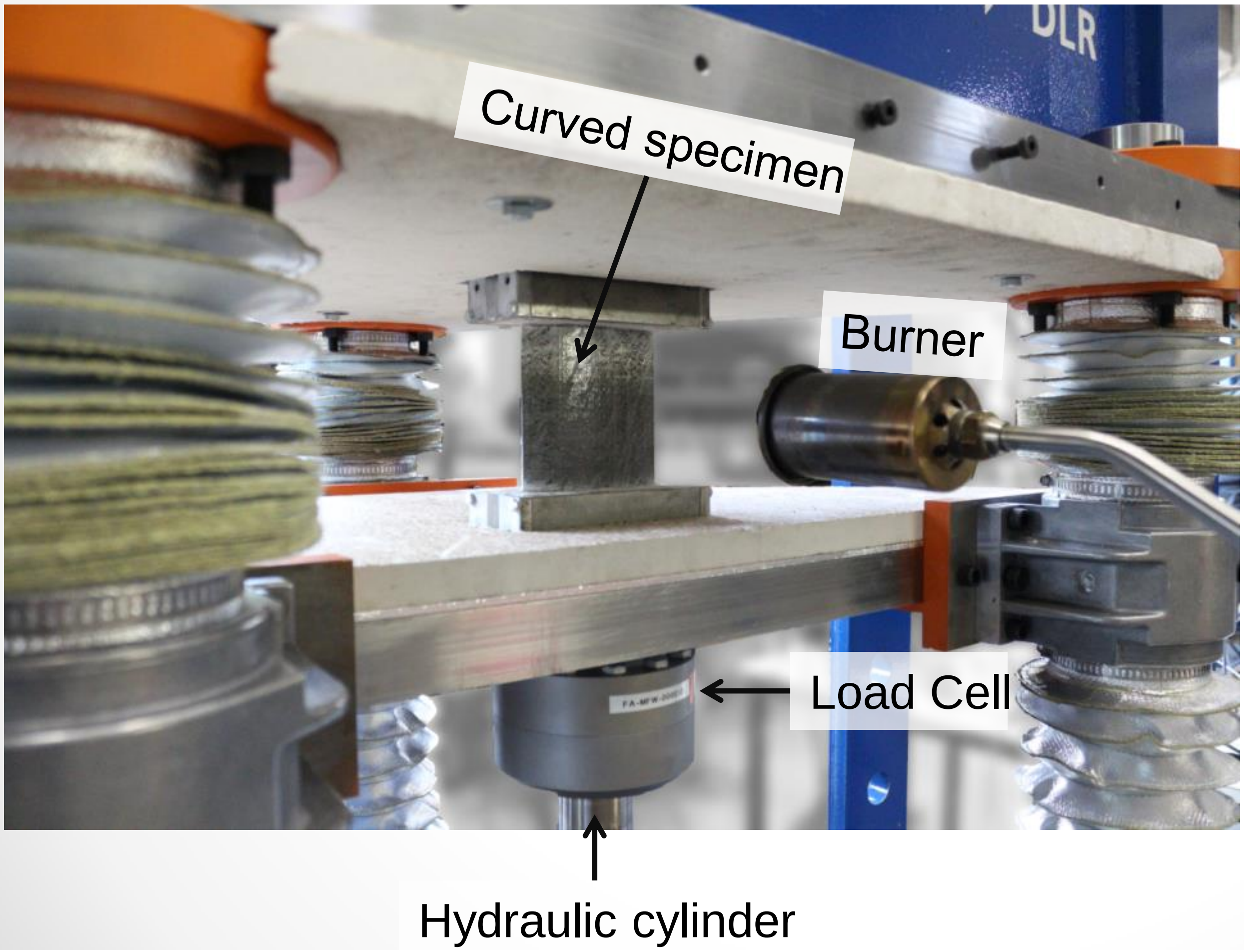
- Aim: Investigate residual mechanical performance within a fire scenario
- New facility that allows combination of mechanical loads and simultaneous fire exposure

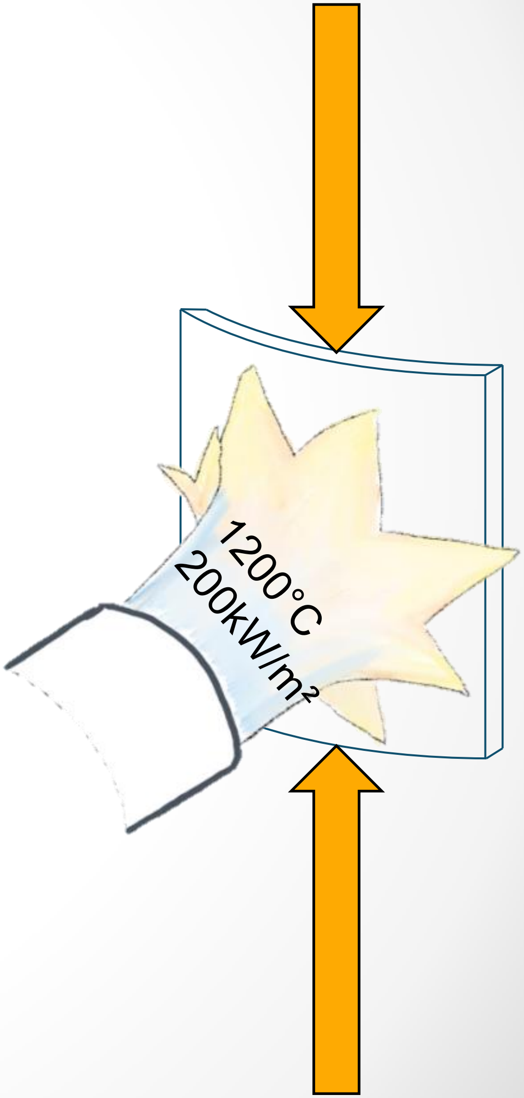
Simple test protocol

- Specimen size: 120mm x 200mm
- Curved specimen to guarantee mechanical stability against buckling
- Quasi-static axial compressive preload (50MPa)
- Fire Loading: Aperture may be used to reduce the exposed surface
- Measurement of force and backside temperature



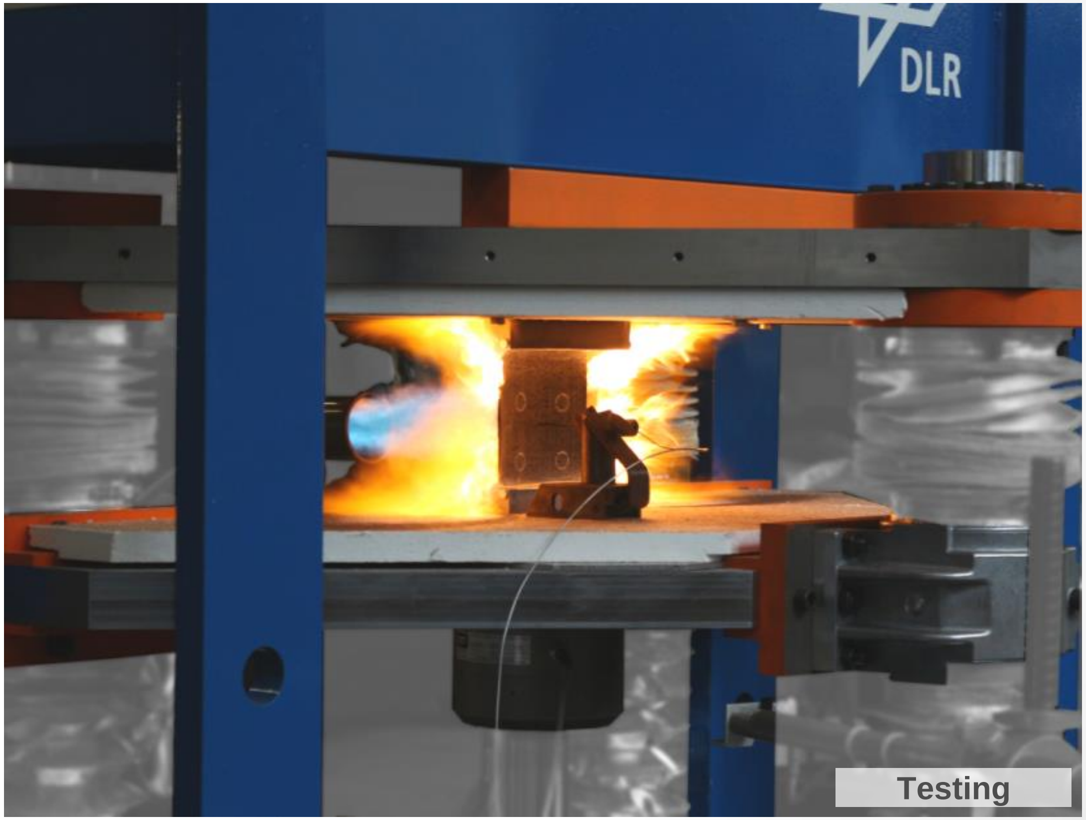
CuFEx facility





CuFEx facility

Specimen backside prepared with thermocouples



Testing

CuFEx facility

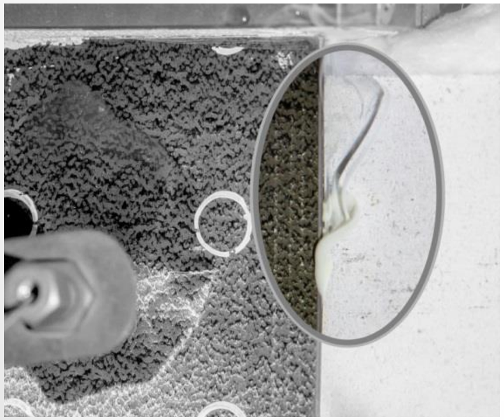

Failed specimen after testing with aperture


Failed specimen after testing


Specimen backside after testing

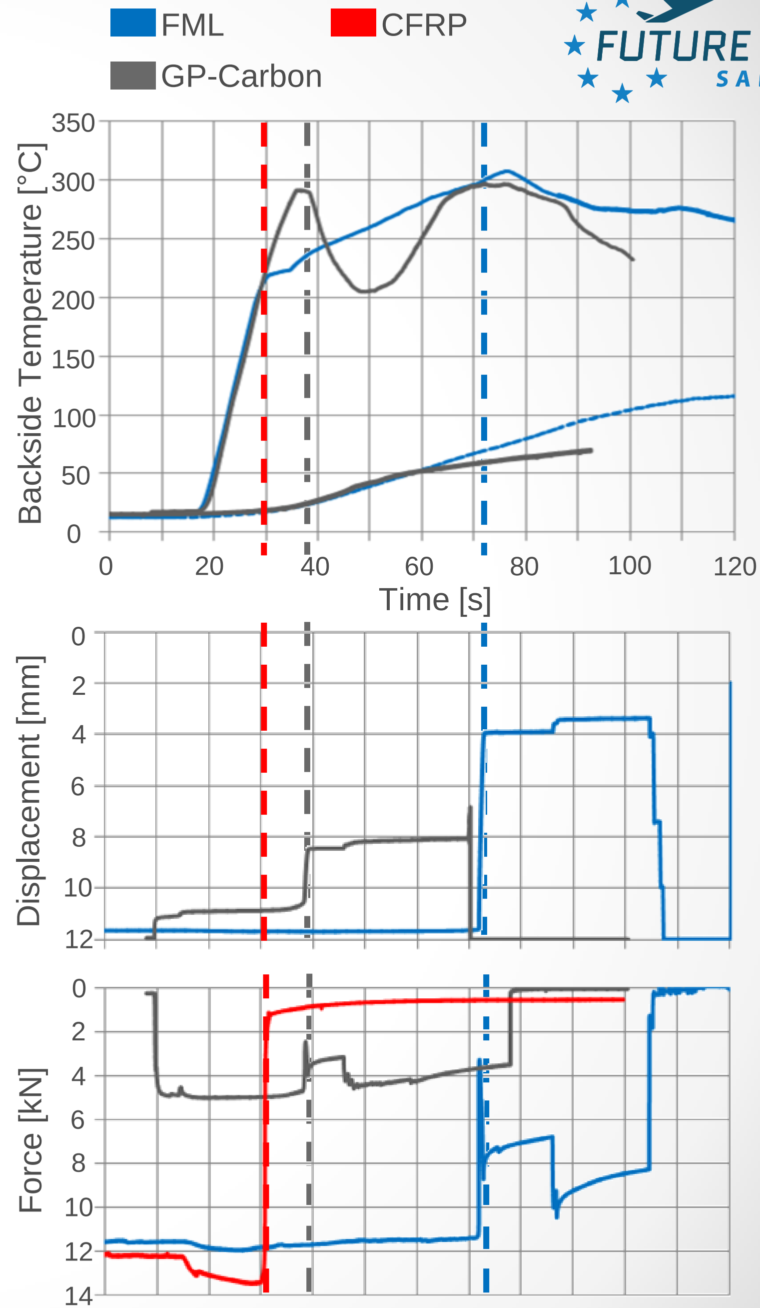
CuFEx test results

- CFRP Reference failing after ≈ 15s
- GP failure after ≈ 25s @ 20MPa due to stability failure
- FML failure after ≈ 55s @ 50MPa introduced by delamination at free edges



Delamination results in leakage of insulating gas

Specimen front after testing, stability failure visible at specimen edges

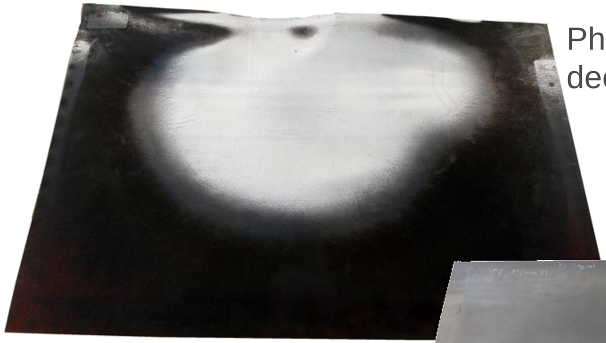


Demonstrator

- Fire tests were conducted to demonstrate the improved FST behavior of aircraft structures through materials investigated within FSS compared to common materials
  - Interior structures: Common: Phenolic-glass compared to GP-carbon
  - Primary/ secondary structures: Aluminium compared to FML

Aluminium: Burn-through after approx. 1min

FML: No burn-through or decomposition on the inner side



Phenolic-Glass: Completely decomposed matrix

GP-carbon: Almost no reactions resulting to fire

Outlook

Geopolymer

- Development of **GP-based honeycomb** for heat resistant sandwich structures
- Development of **GP composites containing ductile layers** to improve toughness

Fibre-metal-laminates

- Further investigations to **derive weight-optimized FML** layups wrt multiple design aspects (FST, fatigue, impact etc.)
- Investigate the promising insulating effect of a FML skin for more representative **stiffened structures** for combined mechanical & fire loading

FUTURE SKY SAFETY

Consortium

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Deutsches Zentrum für Luft- und Raumfahrt
Office national d'études et de recherches aérospatiales
Centro para a Excelência e Inovação na Indústria Automóvel
Centro Italiano Ricerche Aerospaziali
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